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# Palynostratigraphic Study of Pamol Shale Deposits, Calabar Flank, Southeastern Nigeria

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**Abstract**

Pamol shale deposits exposed along Calabar/Odukpani Road, Southeastern Nigeria was investigated to determine its geological age and interpret paleoenvironmental significance based on the recovered palynomorph contents. The lithology is predominantly shale with traces of siltstone and sandstone. The shale is generally light dark, grey to sometimes light brown, subfissile to fissile, moderately hard, carbonaceous, micromicaceous and ferruginized. The microfloral analysis carried out show that the sample consists of pollen and spores with some marine organic walled micro planktons. This constitutes angiosperms (41%), pteridophytes (37%), fungi (13%), dinoflagellate cysts (5%) and foraminiferal lining (4%). The occurrence of age diagnostic palynomorphs such as *Cingulatisporites ornatus, Ephedripites ambonoides, Retidiporites magdalensis, Synolocolporites marginatus, Constructipollenites ineffectus, Foveotriletes margaritae* and *Echitriporites trianguliformis* within the location suggest that the deposition of these sedinents took place during the Early-Late Maastrichtian times. This age determination is equivalent to the *Proteacidites sigali - Echitriporites trianguliformis* and *Cyathidites* spp- *Laevigatosporites haarditti* Assemblage Zones. The paleoenvironmental deposition of the analysed outcrop sediments depicts a marginal marine settings characterized by tropical warm and humid climate.

Keywords: Palynostratigraphy, Palynomorphs, Early-Late Maastrichtian, Pamol shale, Paleoenvironment, Marginal marine, Nkporo Shale and Calabar Flank.

## Introduction

The Calabar Flank is an inland intracratonic basin, located on the north-east part of the petroliferous Niger Delta basin (Fig. 1). The Calabar Flank sedimentary basin has not received much attention of many geologists unlike its adjacent Niger Delta Basin counterpart. This is due to its non-richness in terms of hydrocarbon reserve. However, few works done by scholars on Calabar Flank is mainly on sedimentology, with very little investigation on its palynological aspect. Some of this work include Nyong and Ramanathan (1985); Edet and Nyong (1994); Adegbie and Bassey (2007)); Adegoke, (2012); Itam and Inyang (2015); Itam and Ugar (2016), Itam et al., (2016) and Essien et al., (2016).

Despite these short comings, there is therefore need to carry out detailed study in order to truly understand the stratigraphic pattern of the Calabar Flank in terms of its palynological biostratigraphic investigation, age and paleoenvironmental interpretation. This work is undertaken using outcrops exposure at Pamol Rubber Plantation Estate, along Calabar /Odukpani road (Fig. 2) in Cross River State, Southeastern Nigeria. The co-ordinates for the two studied locations are; Location 1 (L1) is located in N005$^0$03□52" and E008$^0$21□10.5" whilst Location 2 (L2) is at N005$^0$07□10.8" and E008$^0$21□29.0" respectively.

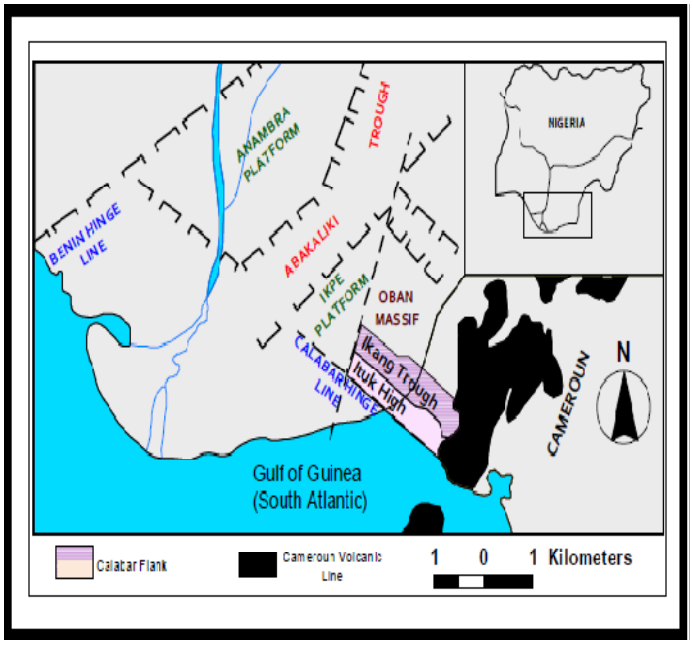



**Figure 1. Map showing Calabar Flank location with respect to the Benue Trough (Nyong and Ramanathan, 1985).**

## Geological setting and stratigraphy of the Calabar Flank

The Calabar Flank is an epirogenic sedimentary basin in southeastern Nigeria (Murat, 1972). The basin bounded the Southern rim of Oban Massif in the north, Calabar hinge line which separates the basin from Niger Delta basin in the south, Ikpe platform and Cameroon volcanic trend in the west and east respectively (see fig.1). The origin of this basin is associated with the opening of the South Atlantic in the Mesozoic era when the South American drifted away from African plates. The major tectonic elements operating within the basin include the Ikang Trough (graben structure) and Ituk High (horst) which were mobile depression and stable mobile submarine ridge that initiated sedimentary distribution facies (Murat, 1972 and Nyong, 1995).

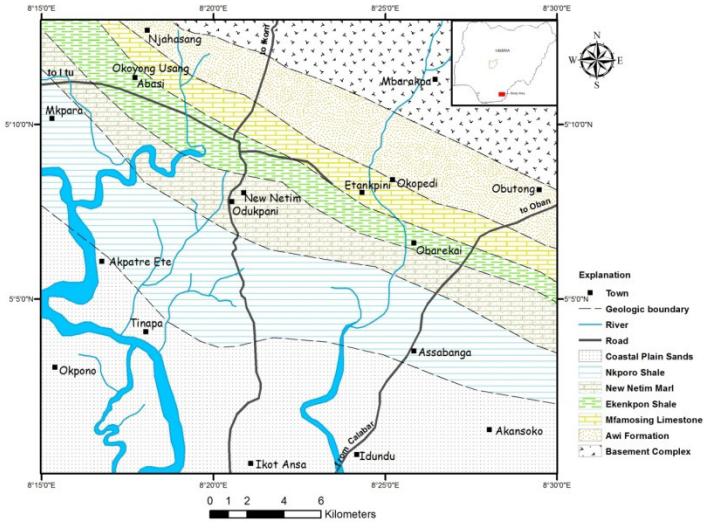
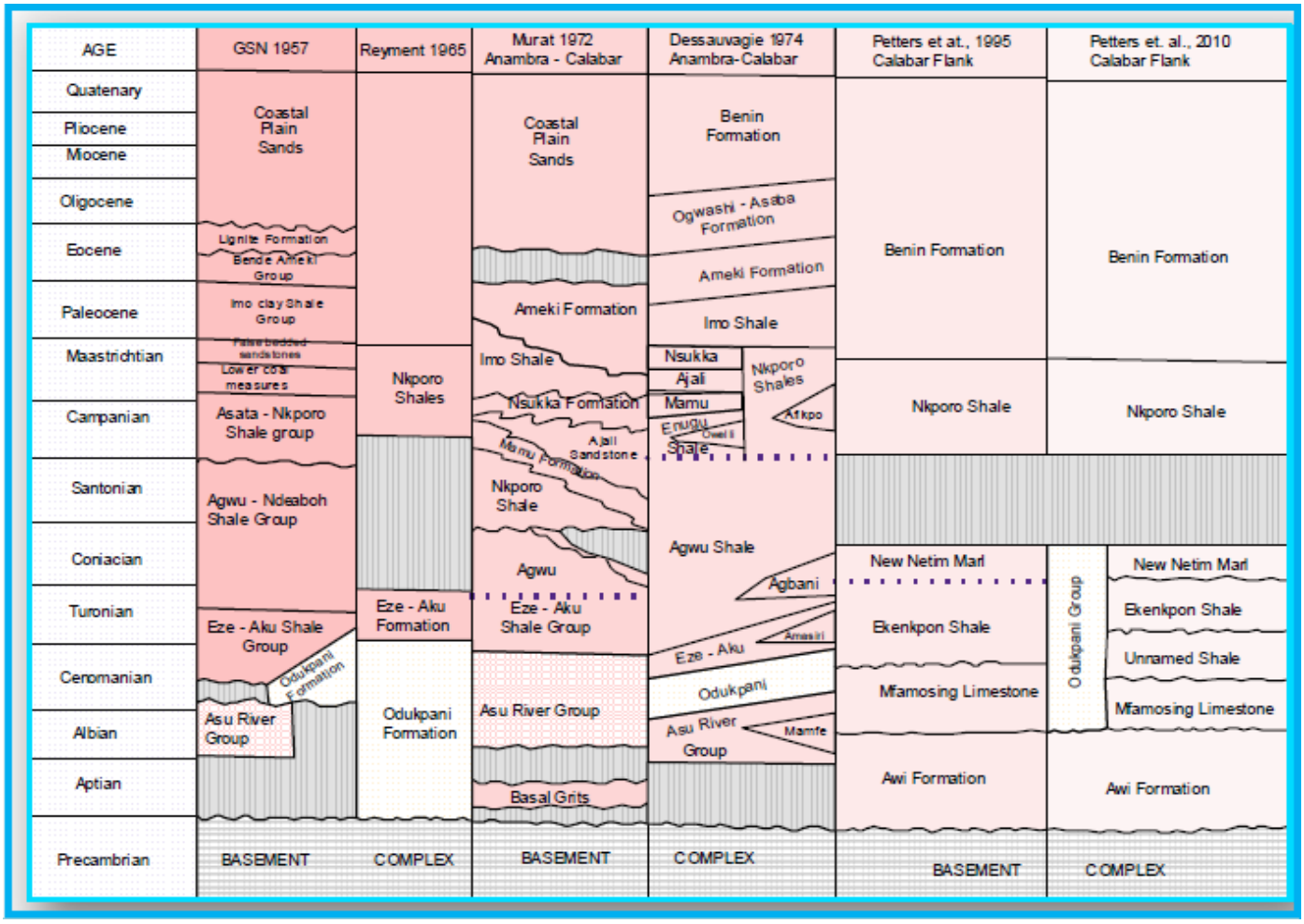



**Figure 2. The geological and location map of the study area.**

The stratigraphic succession of the Calabar Flank is shown in Table 1. Sediment thickness is over 3500m with the onlap or featheredge of the outcropping units north of Calabar, along the fringes of the Oban Massif basement complex. The formations are best exposed along Calabar –Ikom road with its succession which consists of five Cretaceous and Tertary lithostratigraphic units. Awi Formation is the oldest and therefore forms the basal unit and sits non-conformbly on the basement complex of Oban Massif. This formation is Aptian in Age (Adeleye and Fayose, 1978). The Awi Formation is overlain by Mfamosing Limestone of the Middle – Upper Albian age (Petters, 1982 and Nyong and Ramanathana, 1985) and stands as the first marine transgression into the basin. This in turn was succeeded by Late Albian- Cenomanian to Turonian, Ekenkpon Shale (Nyong and Ramanathan,

**Table 1. Stratigraphic correlation between Calabar Flank and other Nigerian sedimentary basins (Nyong, 1995 and Petters et al., 2010).**




1985). Subsidence on the faulted blocks of horst and graben allow wide spread deposition of shales with minor marl and mudstone intercalation. However, the New Netim Marl of Coniacian (Petters et al., 2010) in age succeeded the Ekenkpon Shale. Conversely, the Santonian period was marked by a major unconformity in Nigeria. One of the key published facts noted about the Nkporo Shale is that it is Late Campanian to Early Maastrichtian in age (Edet and Nyong, 1994) and it capped the marine transgression and Mesozoic sedimentation in Calabar Flank. The Tertiary fluvial sands belonging to the Benin Formation completes the sedimentation episode in the basin. This formation is designated Miocene in age based on the palynofloral content occurrences (Itam et al., 2016).

## Materials and Method

The samples used for this research work was collected around Pamol Rubber Plantation Estate along Calabar/Odukpani road, Southeastern Nigeria. The collected samples from two locations were labeled and stored in sample bags. A standard palynological analysis procedure was followed in the laboratory, which involve acid maceration, alkali treatment and staining methods. The purpose of this was to help

concentrate the residues and recalled the insoluble organic microfossils. The oxidize residues were later sieved using 5µm mesh nylon with the help of soniter 450 machine mounted on glass slide with Norland adhesive gel. A powered transmitted electronic microscope meant for palynological studies was mounted and used for identification and counting of the palynomorphs. The counting and logging was done simultaneously and coordinates where representative palynomorphs occur were recorded with England finder. Relevant publications from schalors and palynological photo album of Shell Petroleum Development Company (SPDC) were used in the identification of the recovered palynomorphs. Morphologic features of the pollens and spores such as sites, exines, shapes, structures, apertures and sculptures were taken into account while attempting the analysis and the classification of the respective palynomorphs. The species name and their occurrences were also tabulated and noted. Some dinoflagellate cysts and fungal grains which could not be identified due to corrosion or mechanical damage were probably classified as indeterminate dinocysts and fungal species respectively.

## Results and Discussion

### Lithological Analysis

The observed lithofacies of the samples are predominantly made up of shale deposits. The shale is dark grey to black in colour, fissile and slightly ferruginized. There are minor occurrences of gypsum and pyrite minerals coupled with fish teeth and glauconitic materials which occur as accessories. The lithofacies of these outcropping sediments probably suggest deposition in a nearshore setting. Lithologically, the fissility character exhibited by this shale deposits infers its depositional processes as being dominated by quiet and low energy in a reduced setting possibly in a transitional environment associated with deltaic processes.

### Palynological Analysis

A total of thirty (30) species of pollens, spores and dinoflagellate cysts were identified and recorded from the studied sediments. The studied sections yielded fairly to moderately abundance and diversified palynomorphs however, due to the probable highly weathered and ferruginized nature of the settings some grains were therefore affected in terms of their preservation mode. Some of the key palynomorphs encountered within these locations are represented in attached plate I.

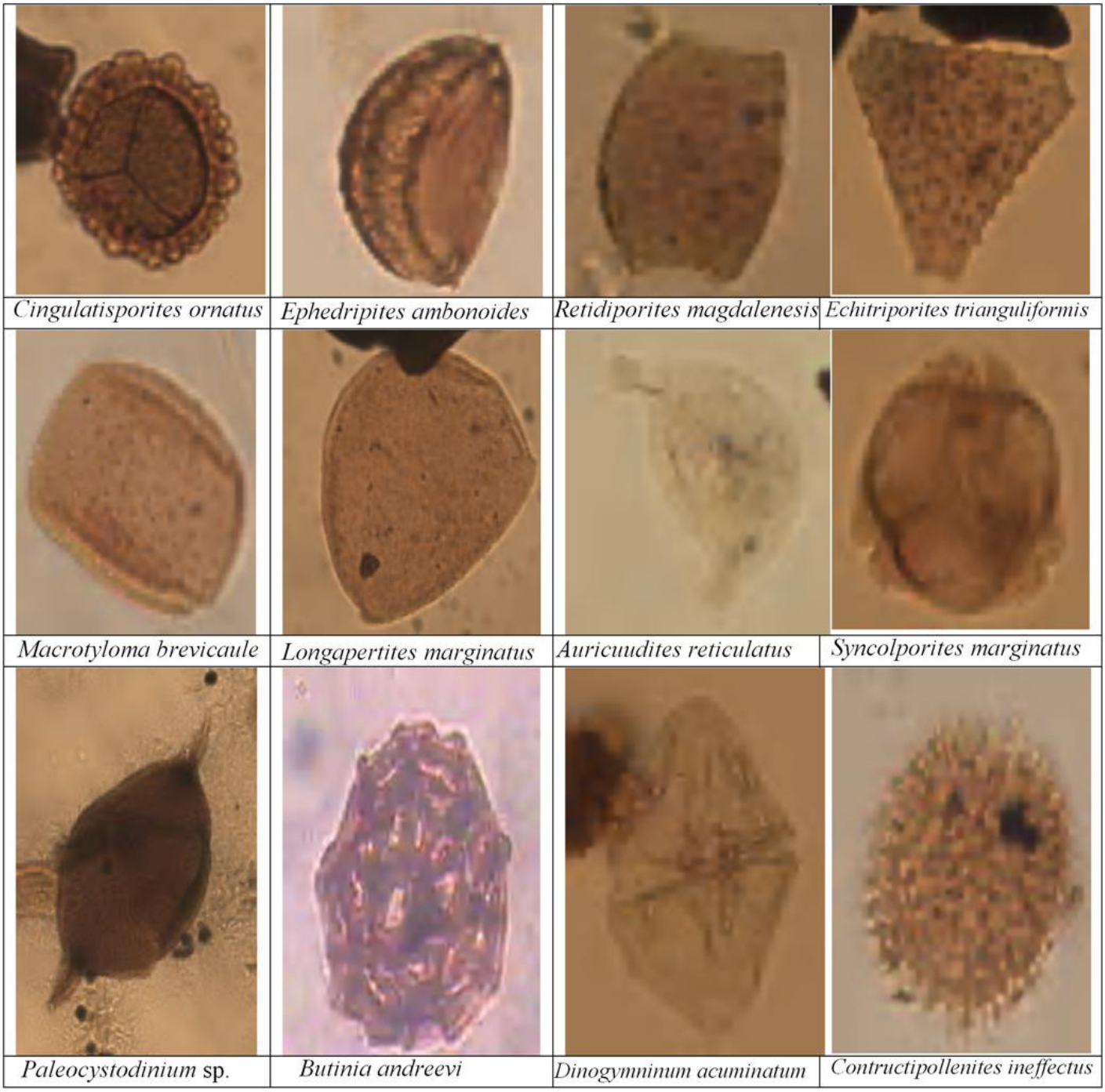
The breakdown of the result showed that a total of one hundred and eleven (111) palynomorphs was recovered, consisting of forty (40) pollens, thirty-eight (38) spores, twenty-seven (27) dinoflagellates cysts and six (6) fungi respectively.

A total of fifteen (15) diagnostic species of pollens were identified from the picked sediments and this includes; *Baculatriporites orluensis*, *Circulina parva*, *Constructipollenites ineffectus*, *Ephedripites ambonoides*, *Ephedripites multicostatus*, *Ephedripites* sp., *Munocolpopolenites sphroidites*, *Proteacidites longispinosus*, *Psilatricolporite*s sp., *Retidiporites magdalenesis*, *Retidiporites* sp., *Retitricolpites punctatus*, *Striamonocolpites undatostriatus* and *Synocolporites marginatus*. However, the spore assemblage is made up of eleven (11) species which include *Adenantherites* sp., *Azolla* sp., *Cingulatisporites ornatus*, *Cyathidites autralis*, *Fusiformisporites* sp, *Foveotriletes margaritae*, *Leiotrilites adriennis*, *Rugulatisporites caperatus*, *Vadasisporites sacali*, *Verrucosisporites* sp. And Fungal spores. Three species of dinoflagellates recovered and identified are *Paleocyctodinium gabonense, Paleocystimum* sp. and dinocyst

## PLATE 1

**The photomicrograph of key palynomorphs from the study area. Mag. X25 (For all the palynomorphs).**



indeterminate. The only algal prasinophytes identified in the study area is *Pterospermella* sp.

**Non- marine palynomorphs assemblage**

The non-marine indicator palynomorphs assemblages are the dominant group occurring within the study area. It was observed that this non-marine palynomorphs is over 78% of the total palynomorphs consisting of pollen and spores species. The pollen and spores assemblages have much variation and are made up of angiosperm, gymnosperm, pteridophytes and fungi spores belonging to several generic groups. The angiosperm constitutes about 41% and is essentially monocolpate, tricolpate and tricolporate species. On the other hand, the pteridoplytes (31%) are dominated by trilete spores while the gymnosperm pollen constitute inaperturateae pollen (*Ephedripites*) while the fungi spores is dominated by monolete species and constitute 13% of the total assemblage species encountered within the sediments. Conversely, the spore and pollen assemblages suggest a mixed coastal and inland subtropical forest dominated by angiosperm taxa, which were more abundant and diverse at various times during the deposition of the Early – Late Maastrichtian sediments which correspond with Nkporo Shale Formation. Dinocysts elements seen were depicting inner neritic dwellers thereby reflecting nearshore deposition of the sediments. The palynofloral elements, which probably suggest nearby coastal forest vegetation, consist of ferns, mosses, lycopods, cycads, gymnosperms and palms respectively.

**Marine palynomorphs assemblage**

The marine palynomorphs assemblage is made up of dinoflagellate and prasinophyte group constituting 8% of the total population. The organic walled microplankton dinoflagellates of peridiniod type constitute the dominant species of this assemblage.

**Age Determination**

The presence of the following recovered index pollen, spore and dinoflagellate markers such as *Cingulatisporites ornatus, Ephedripites ambonoides*, *Retidiporites magdalensis*, *Synocoloporites marginatus*, *Constructipollenites inetfectus*, *Foveotriletes margaritae*, *Psilatricolporites* sp., *Proteachidites longispinosus*, *Butinia andreevi, Rugulatisporites caperatus* and *Paleocystodinium* sp. enhanced the dating of the studied sections. However, based on the occurrences of those diagnostic microfossil grains, the sediments found within this environment is dated Early-Late Maastrichtian age. This age determination is in conjunction with the works of Ojo and Akande (2006); Soronnadi-Ononiwu, et al., (2012); Boboye (2013); Ola-Buraimo (2012); Ola-Buraimo and Akaegboi (2013); Chiaghanam et al., (2013); Nwojiji et al., (2013) and Onoduka and Okosun, (2014). Some of these markers palynomorphs have been reported by Ola- Buraimo (2012). Nwojiji et al, (2013), Onoduku and Okosun (2014) and Ola-Buraimo et al., (2014) unveiled this section to be equivalent to those recovered and identified from various Maastrichtian sediments in other Nigerian intrabasins and of Senegal, Ivory Coast, Gabon, Angola, Egypt, Morocco and Brazil (Jan Du Chene et al., 1978; Salard- Chadoldaeff, 1990 and Oloto, 1994). The age range zones of this studied section is equivalent to the two informal palyzones of Onoduku and Okosun (2014) which are *Proteacidites sigali - Echitriporites trianguliformis* and *Cyathidites* spp- *Laevigatosprite haardilti* Assemblage Zones of Early - Late Maastrichtian age respectively. The *Proteacidites sigali -Echitriporites trianguliformis* Assemblage Zone is marked by the occurrence of index palynomorphs such as *Retidiporites magdalenesis*, *Cyathidites* sp, *Proteacidite* sp and *Rugulatisporites caperatus*. This corresponds to lower *Spinizonocolpites baculatus* zone of Lawal and Moullade (1987). The *Cyathidites* spp-

*Laevigatosprite haardilti* Assemblage Zone from this studied section consists of mainly *Cyathidites* sp. and *Longapertites* sp. and is equivalent to *Spinizonocolpites baculatus* Zone of Lawal and Moullade (1987).

**Paleoenvironmental Interpretation**

The interpretation of paleoenvironmental settings of the studied area was carried out utilizing the analysed palynomorphs. This followed an approach adopted by a good number of scholars who used palynomorphs data to determine the environments of deposition of sediments within this age range (Schrank, 1994; Edet and Nyong, 1994 and Ojo and Akande, 2001 and Ola-Buraimo and Adeleye, 2010). A comparison of land derived palynomorphs to marine source of organic walled micro plankton that combines pollen and spores frequency was adopted in this study. The analyzed samples show that the combine pollens and spores have percentage frequency of 78% while dinoflagellates and acritarch give about 22% respectively. This shows that the study section is dominated with abundant of organic debris, which suggests proximity to land and a high runoff from adjacent terrain which actually cause reduced salinity. Also the influx of these terrestrial materials over the marine palynomorphs could have led to the dilution of the environment which is evidence from the low quantity of marine dinaflagellate cysts and *peterospermella* (prasinophytes) in the studied section.

A semi-quantitative interpretation referred to as Palynological Marine Index (PMI of Helenes et al., 1998) was employed to infer the depositional environment. The formula is given as PMI = $(R_m/R_t+1)100$, where $R_m$ = number of marine palynomorphs (Dinoflagellates + Acritarch + Prasinophytes + Foraminifera linings).$R_t$ = number of land/terrestrial palynomorphs (Pollen + Spores + Fungal remains). The analyzed result has PMI value of 147. This infers fluviomarine depositional setting where the coastal setting falls within the nearshore zone.

The presence of some palmae pollens including *Psilatricolparites*, *Constructipollenites*, *Longapertites*, *Retidiporites*, *Syncolporites*, *Monocolpopollenites* and pteridophytes dominated by the trilete spores however suggested that the land was predominantly warm and humid depicting a tropical climate in the studied section. The high dominancy assemblage of palm pollen is equivalent to the microfloral occurrences in the Anambra Basin of the Eastern Nigeria and can be referred to as part of the Late Cretaceous Palmae Province of Africa, South America and India (Ononduku and Okosun, 2014; Hangreen, 1980). According to Morley, (2000) these palms are often dominated in coastal and mangrove vegetated regions. The dominant of angiosperm over gymnosperm species in this study denoted the flourishing of flowering plants during the Cretaceous time.

**Paleovegetation**

The paleo-vegetation of the Palmo Shale sediments in the Calabar Flank is similar in age to the Campanian – Maastrichtian Enugu and Mamu Formations of Anambra Basin in Nigeria (Omigbo et al., 2015) and therefore consists of:

1. Mangrove vegetation: This is primarily interpreted from abundance of *Spinizonocolpites* and *Psilatricolporites* elements.

2. The back-mangrove vegetation: These are characteristics by two major elements *Monocolpopollenites* and *Longapertites* genera.

3. Pteridophytic vegetation: dominated by trilete spores.

4. Fungi: Has occurrences of Fusiformisporite and fungispores.

The elemental compositions of mangrove and back-mangrove species infer an ecosystem of mangrove swamp, brackish water of humid tropical setting (Schrank, 1994; Helenes et al., 1998 and Herngreen, 1980). This may also infer depositional system of estuary and tidal flat/marsh while fungi and pteridophytes spores suggest fresh water swamp and marsh areas.

## Conclusion

The palynological analysis carried out on the Pamol shale exposed along Calabar/Odukpani Road, Southeastern Nigeria showed that the shale consists of shale that is dark grey to black in colour, fissile with minor ferruginizitaion at some points. The palynological grains are made of pollen (angiosperm and gymnosperm), spores (pteridophytes and fungi) and marine palynomorphs (dinoflagellates cysts and prasinophytes). Base on index palynomorphs recovered and identified from the section, the age of the studied area penetrated belongs to the Early – Late Maastrichtian and corresponds with Nkporo Shale of Calabar Flank. The paleo-ecosystem is interpreted as mangrove swamps of tropical humid climate. The depositional setting of the analysed section is observed to occur within the mangrove swamp of tidal marsh/flat and estuarine depositional settings. This study therefore serves as a correlating platform for regional studies with other intrabasins utilizing palynomorps and therefore forms the basis for a better understanding of this basin in terms of palynostratigraphy and paleoenvironmental interpretations.

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